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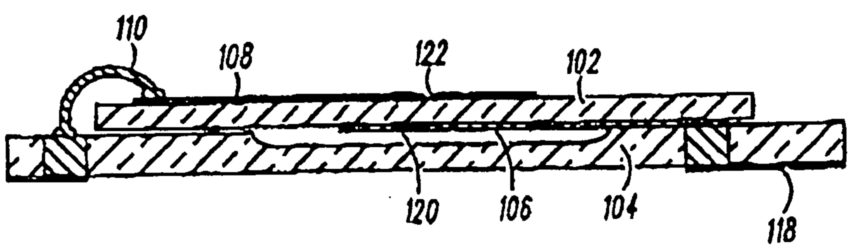

(57) Abstract

A method and device for mounting a piezoelectric element in a package without the use of adhesives. The piezoelectric device includes a substrate (104) with at least two electrical traces (118), a piezoelectric element (102) with a top electrode (108) and a bottom electrode (106), and a wirebond ball bump (100). The ball bump is ultrasonically bonded to one of the electrical traces (118) on the substrate (104), and the bottom electrode (106) of the piezoelectric element (102) is ultrasonically bonded to the ball bump (100). A wirebond (110) connects the top electrode (108) with the remaining electrical trace (118) of the substrate (104). The device is provided in a conventionally sealed package.

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WO 98/19349 PCT/US97/15106

AN ULTRASONICALLY MOUNTED PIEZOELECTRIC DEVICE AND METHOD OF MAKING SAME

Field of the Invention

This invention relates to piezoelectric devices, and more particularly, to a method and apparatus for ultrasonically mounting a piezoelectric device in a package without using adhesives.

Background of the Invention

Piezoelectric devices, such as piezoelectric quartz filters, piezoelectric quartz resonators and the like, typically comprise a piece of piezoelectric material mounted to a substrate. In quartz devices, the quartz element of necessity has thin metallic electrodes attached to it through which electrical signals are coupled into and out of the piezoelectric quartz material. Common problems with piezoelectric devices are providing good electrical contact with the electrodes while sufficiently isolating the piezoelectric devices from mechanical shock and dealing with mismatches in thermal expansion coefficients of the piezoelectric device and the substrate material. In addition, the adhesives solutions used in mounting piezoelectric devices typically contain residual chemical by-products which accumulate on the surface of the piezoelectric device during its lifetime causing a frequency effect referred to as aging.

Quite often, the components of the piezoelectric devices, such as a piezoelectric quartz material and the substrate, have different thermal expansion coefficients. This mismatch causes mechanical stresses to be induced in the quartz during the life of these devices as the quartz and substrate expand and contract over temperature variations. As is well known in the art, mechanical stresses in a quartz blank causes the inflection temperature of the Bechmann curve of the device to shift upwards. Further, mechanical shock transferred to the quartz through its mounting structure can increase mechanical stresses that, in addition to the thermal stress, adversely affect the frequency and accuracy of these devices. In addition, the adhesives generally used to mount piezoelectric devices can change electrical properties during temperature excursions experienced during the life of the device due to continuing chemical reactions to the temperature changes. Also, the adhesive solutions are typically contained within a hermetic space of the device package. This maximizes the effect on the device of any chemical by-product emitted from the adhesive after the device is sealed.

Some prior art mounting techniques have used conductive epoxy, silicone and solder. These adhesives all use chemical binders, fluxes and the like to work properly. These chemical by-products work to the detriment of the piezoelectric device over its lifetime. In addition, most, if not all, of the prior art mounting schemes are difficult to use because of the small physical dimensions that modern piezoelectric quartz elements have. All of the adhesives mentioned are difficult to dispense or apply in very small amounts. Conventional piezoelectric devices using these adhesives have had marginal results, frequency shifting,

increased mechanical stresses, poor shock resistance, and large unwanted frequency shifts over the times and temperature ranges of interest.

In FIGs. 1 and 2, a prior art epoxy mounted piezoelectric device is shown, which includes an epoxy dot 10 coupling a quartz resonator 12 to a substrate 14. The size of the epoxy dot 10 is relatively large to provide sufficient electrical and mechanical connection. In addition, it is difficult to reliably dispense smaller epoxy dots. The large size of the dots 10 requires a large separation between electrical connections on a bottom electrode 16 of the device or the substrate 14. The large separation is necessary to prevent the adhesives from flowing together during device placement causing a shorted electrical connection. This large separation contributes to increased mechanical stress distributed into an active area of the device which changes the frequency performance of the device over temperature. Also, the chemical binder by-products in the adhesive outgasses during the life of the device thereby further affecting frequency. In addition, more chemical adhesive is needed to make an electrical connection to a top electrode 18 of the device if a wirebond 20 is not used.

There is a need for an improved piezoelectric device, having reduced frequency-temperature shifts, to: minimize the mechanical stresses induced due to the thermal expansion mismatches between the substrate and device over temperature, provide a mechanically sufficient coupling such that the device can withstand mechanical shock, provide an electrically sufficient coupling from the substrate to the electrode, minimize frequency shifts over the lifetime of the device, and provide a method of crystal attachment which is adaptable to mass production.

Accordingly, a low cost, readily manufacturable, higher quality mount for a piezoelectric device would be an improvement over the prior art. A method by which quartz devices can be easily and reliably attached to a substrate and which isolates the quartz element from mechanical stresses and chemical contamination would also be an improvement over the art.

Brief Description of the Drawings

FIG. 1 shows a top plan view of a prior art epoxy mounted crystal resonator;

FIG. 2 shows a cross-sectional view of the prior art epoxy mounted crystal resonator of FIG. 1;

FIG. 3 shows a top plan view of an ultrasonically mounted piezoelectric device, in accordance with the present invention;

FIG. 4 shows a cross-sectional view of the ultrasonically mounted piezoelectric device of FIG. 3;

FIG. 5 shows a cross-sectional view of an alternative embodiment of an ultrasonically mounted piezoelectric device, in accordance with the present invention;

FIG. 6 shows a preferred embodiment of a sealed package incorporating the ultrasonically mounted piezoelectric device of FIG. 3, in accordance with the present invention;

FIGs. 7-10 show various stages in connection with one embodiment of a method to ultrasonically mount a piezoelectric device, in accordance with the present invention;

FIG. 7 shows a cross sectional view of a provided piezoelectric element and substrate, in accordance with the present invention;

FIG. 8 shows a cross sectional view of the piezoelectric element positioned on the substrate, in accordance with the present invention;

FIG. 9 shows a cross sectional view of the piezoelectric element and substrate during application of ultrasonic power, in accordance with the present invention;

FIG. 10 shows a cross sectional view of wirebonding an electrode of the element to the substrate, in accordance with the present invention;

FIGs. 11-15 show various stages in connection with a preferred embodiment of a method to ultrasonically mount a piezoelectric device, in accordance with the present invention;

FIG. 11 shows a cross sectional view of a substrate with a seal ring being wirebonded, in accordance with the present invention;

FIG. 12 shows a cross sectional view of the substrate with a wirebonded ball bump, in accordance with the present invention;

FIG. 13 shows a cross sectional view of a piezoelectric element being held and ultrasonically bonded to a contact point of the ball bump, in accordance with the present invention;

FIG. 14 shows a cross sectional view of wirebonding an electrode of the element to the substrate, in accordance with the present invention; and

FIG. 15 shows a cross sectional view of a lid sealed to the seal ring of a package body, in accordance with the present invention.

Detailed Description of the Preferred Embodiment

FIGs. 3 and 4, show an ultrasonically mounted piezoelectric device which includes a substrate 104 having at least one substantially upwardly facing planar surface, a piezoelectric element 102 having an upwardly facing surface including a top electrode 108 and a downwardly facing surface including a bottom electrode 106. The device includes at least one wirebond ball bump 100 coupling the element 102 to a substrate 104. The size of the bump 100 is relatively small compared to prior art adhesives, yet the bump 100 provides a sufficient electrical and mechanical connection between at least one electrical trace 118 on the substrate 104 and a bottom electrode 106 on the piezoelectric element 102. The small diameter of the bump 100 advantageously allows a smaller pitch between electrical traces than can be achieved by adhesive dots. This reduction in size enhances miniaturization of the piezoelectric element 102. The electrical trace 118 may provide an external connection through a via, as shown, or through a castellation, both of which are known in the art.

The bump 100 can be made of any standard wirebond material such as aluminum, silver and gold. Preferably, the bump 100 is made of gold or a gold alloy to provide a high quality, chemically inert ultrasonic bond between the bottom electrode 106 of the element 102 and the bump 100 and between the bump 100 and the electrical trace 118 of the substrate 104. Also, the electrical conductivity of the bumps 100 is much better than is available via conductive epoxies or silicones. The bumps 100 are bonded to the substrate 104 using known ultrasonic or thermosonic wirebonding

techniques. Bumps 100 have been produced with standard 28µm gold wire using a K&S 1482 wirebonder. The resultant bumps 100 have a nominal height of about 125µm and a diameter of about 125µm. This is in comparison to the typical 75µm height and 750µm diameter of cured epoxy dots. It should be recognized that the use of larger diameter wire will produce larger bumps. Also, it is advantageous to have higher mounting bumps as this helps reduce mechanical stresses in the element 102 due to thermal mismatches between the substrate 104 and the element 102, and improves mechanical shock performance as the element 102 is free to travel farther under mechanical shock before striking the substrate 104.

In general, a wirebonder will place a ball bump 100 much more repeatably than the dispensing of adhesive dots. This repeatability allows close placement of the bumps 100 without the problem of the bumps 100 shorting together. Repeatability of placement is better than 25µm, typically. Also, the height of the bumps 100 is better controlled by a wirebonder than compared to the dispensing of adhesive. The close placement of bumps concentrates any mechanical stresses, due to thermal mismatches between the element 102 and the substrate 104, into a much smaller area of the piezoelectric element 102. This smaller area localizes the mechanical stresses away from the active area of the piezoelectric element 102. This is in contrast with the use of adhesive dots where a large separation between dots contributes to increased mechanical stress distributed into an active area of the element changing its frequency performance over temperature. Further, due to the small size of the bumps, they may be used to mount a piezoelectric

element at its nodal points, thereby providing support without substantially damping the piezoelectric vibrations.

The device shown in FIG. 4 shows an element 102 mounted in a cantilever fashion where a right side portion of the element 102 is mounted to the substrate and a left side portion is free. In one embodiment, the element 102 may be supported, but not mounted, under a left side portion of the element 102. This support may consist of a ceramic extension from the substrate 104 or an additional ball bump which is bonded to the substrate 104 but not the element. The purpose of the support would be to improve mechanical shock performance of the device and to facilitate wire bonding of the top electrode 108 to the substrate 104 via the wirebond 110 without flexing the element 102. Also, it should be recognized that the wirebond to the top electrode 108 may be placed on top of the right side portion of the element 102 near to the mounting ball bumps 100. The advantage of this arrangement is that mechanical stresses in the active area of the element 102 is further reduced.

In an alternative embodiment shown in FIG. 5, the piezoelectric element 102 has an ultrasonically formed coupling directly with the electrical trace 118 of the substrate 104. In general, this involves having the electrical trace 118 of the substrate 104 and the bottom electrode 106 of piezoelectric element 102 be of the same material, preferably gold. However, it should be recognized that dissimilar metals can be bonded ultrasonically. In the alternative embodiment, a relief area 120 is made in the substrate 104 directly below the active area 122 of the piezoelectric element 102 so as to prevent damping of the element vibrations. This embodiment has the advantage of

eliminating a processing step and provides for a very low profile package.

To maintain a chemically inert hermetic environment, it is desirable to seal the device in a package using chemical free techniques. Three of the most prominent, preferred sealing techniques for sealing without chemicals are cold welding, resistance welding, and seam welding. All three techniques are known in the art and will work equally well. The preferred embodiment of the package, shown in FIG. 6, uses seam welding, where a metal lid 112 is seam welded to a package body 114 which includes a ceramic substrate 104 and an attached seam weld ring 116. With these features, the yields of the end product package can be improved which results in less waste or scrap in the front end operations of quartz crystal manufacturing.

The piezoelectric element can comprise a number of different types of crystals, such as, but not limited to, AT cut quartz crystals, BT, CT, DT and GT as well. In one embodiment, the piezoelectric element comprises an AT cut quartz crystal with a frequency response over temperature described by the well-known Bechmann curve. The AT cut quartz crystal can be cut in a variety of ways, and in a preferred embodiment, it is cut at about 35 degrees relative to a Z axis thereof. Cuts slightly above or below this value can result in crystals which suffer from frequency instability over temperature. With an AT cut quartz crystal, the first order coefficient of the equation describing the Bechmann curve is substantially or nearly zero, such that frequency change over temperature is decreased or minimized.

In another embodiment, the piezoelectric element comprises a GT cut quartz crystal. The GT cut crystal is very

sensitive to its mounting and benefits by being mounted at a nodal point of its vibration. The nodal point of a GT cut crystal occurs substantially at a center of the element, and the smaller that the contact point can be made the less disturbance there is of the plate vibrations and the temperature response of the element. The use of a wirebonded ball bump provides a much smaller contact mounting point than is available with prior art adhesives. Alternatively, ball bumps can be preapplied to the center of the piezoelectric element and the ball bumps subsequently solder reflowed to a conductive trace on the substrate. This provides for easier assembly.

The reduction of the mechanical stress in the AT cut piezoelectric element due to the small mounting area advantageously results in lowering the inflection temperature of the well-known Bechmann curve of the element, thereby moving the inflection temperature down and towards the middle of a temperature range of interest. A lowering of the inflection temperature substantially centers the Bechmann curve within many customer's specifications, which can result in substantial increases in manufacturing yields, because the Bechmann curve is more centered in the temperature range of interest. This can decrease the number of out-of-specification devices. In one embodiment, the inflection temperature of the Bechmann curve is about 25 degrees C or less, and preferably ranges from about 21 degrees C to about 23 degrees C for improved quality and manufacturing yields.

Lower inflection temperatures are beneficial in the manufacture of temperature compensated crystal oscillators. By having the inflection temperature near a center of a desired temperature range, a symmetric compensation

function can be utilized. The symmetry allows much easier compensation algorithms. Also, reduced stresses result in production groups of crystal having repeatable inflection temperatures. This results in tighter tolerance piezoelectric crystals utilizing less exact crystal angles and providing higher yields.

A method of ultrasonically mounting a piezoelectric element to a substrate comprises the following steps. The first step 200 includes providing a substrate 104 and a piezoelectric element 102, as shown in FIG. 7. The substrate 104 has at least one substantially upwardly facing planar surface and is preferably plasma cleaned. The substrate 104 includes at least one conductive point 124 electrically coupled with at least one conductive trace 118 disposed on the substrate 104 so as to provide external electrical connection to the conductive point 124 . The piezoelectric element 102 has an upwardly facing surface including a top electrode 108 and a downwardly facing surface including a bottom electrode 106.

The next step 202 includes positioning the bottom electrode 106 of the element 102 in contact with the at least one conductive point 124 of the substrate, as shown in FIG. 8.

The next step 204 includes applying ultrasonic energy through an ultrasonic tool 126 to the conductive point 124 so as to bond the bottom electrode 106 to the conductive point 124, as shown in FIG. 9, while applying a predetermined amount of downward pressure 127. The bond occurs as the ultrasonic energy scrubs the bottom electrode 106 against the conductive point 124 until the materials of the bottom electrode 106 and conductive point 124 bond. Although it is not necessary that the materials of the bottom electrode 106

and conductive point 124 be the same, it is preferable that they be the same, and more preferably be of gold.

In a preferred embodiment, an additional step is added before the positioning step. In this step, at least one conductive bump is wirebonded to the substrate. The bump defining the conductive point electrically coupled with the at least one conductive trace.

In one embodiment, the positioning step includes holding the element in position over the contact point with a vacuum chuck, applying downward pressure to the element so as to form a contact point between the bottom electrode and the conductive point, and applying ultrasonic energy to the upwardly facing surface of the element at a point substantially opposite the contact point so as to form an ultrasonic bond at the conductive point. Preferably, this step includes applying thermal energy to the contact point so as to form a thermosonic bond at the contact point. In another embodiment, the holding step includes holding the element in position over the contact point with an ultrasonic tool which includes an integral vacuum port for holding the element.

Placing a wirebond bump on a substrate is known in the art. However, the ultrasonic bond at the conductive point requires the application of about three times the normally required ultrasonic power at a position on the upwardly facing surface of the element which is substantially opposite the contact point. Although the quartz of the element is a good transmitter of ultrasonic energy, it is of benefit to provide some metal plating, preferably gold, at the position on the upwardly facing surface where the ultrasonic energy is applied. The gold improves energy transfer through the quartz.

Additional steps may include connecting the top electrode 108 of the element 102 to a second conductive trace 118 of the substrate 104, as shown in FIG. 10. Preferably, this is done by wirebonding a wirebond 110 to connect the bonding trace 134 of the top electrode 108 to the second conductive trace 118. Another step includes providing the substrate with a sealing surface and a lid suitable for sealing to the sealing surface. Preferably, this includes the substrate being of a ceramic with a metal seal ring, and the lid being of a metal. Another step includes sealing the lid to the seal ring by a sealing process to provide hermetic sealing. The sealing process is selected from the group consisting of cold welding, resistance welding and seam welding. Preferably seam welding is used due to the reduced stresses imparted to the element and reduce costs associated with seam welding.

This method provides an improvement in the manufacture of crystals over adhesive mounts known in the art, and can provide higher quality crystals. The present method is particularly adapted for use in the manufacture of crystal resonators and filters, and most particularly adapted for mass production thereof. However, this method can be accomplished by manual means as well.

In more detail, a preferred method of ultrasonically mounting a piezoelectric element to a substrate comprises the following steps, as shown in FIGs 11-15. The first step 200 includes providing a plasma cleaned package body 114 with a sealing ring 128, a lid 112 adapted for sealing to the sealing ring 128, and a piezoelectric element 102. Preferably, the package body 114 includes a ceramic substrate 104 attached with a metal seal ring 128, and the lid 112 is a metal. The package body 114 includes at least

one substantially upwardly facing planar surface and at least two conductive traces 118 for electrically coupling to the piezoelectric element 102. The piezoelectric element 102 has an upwardly facing surface including a top electrode 108 with a bonding trace 134 and a downwardly facing surface including a bottom electrode 106 with a bonding trace 132. The upwardly facing surface of the element 102 also includes an electrically conductive pad 136 positioned at a point substantially opposite the bottom electrode bonding trace 132.

The next step includes disposing at least one conductive ball bump 100 to one of the conductive traces 118 of the package body 114 as shown in FIGs. 11 and 12. Preferably the bump 100 is disposed by an ultrasonic wirebonder and tool 126 and defines a conductive point 124 electrically coupled with the conductive trace 118 disposed on the package body 114 so as to provide external electrical connection to the point 124.

The next step 202 includes positioning the bottom electrode bonding trace 132 to be in contact with the conductive point 124 of the bump by use of a vacuum chuck 130 holding the element 102, and applying downward pressure 127 to the element 102 so as to form a contact point (shown as 124) between the bonding trace 132 of the bottom electrode 106 and the conductive point 124, as shown in FIG. 13.

The next step 204 includes applying ultrasonic energy at the conductive pad 136 so as to transmit ultrasonic energy to the contact point (shown as 124) through the conductive pad 136, the piezoelectric element 102 and bottom electrode bonding trace 132 such that the bottom electrode bonding trace 132 is ultrasonically bonded to the conductive point

124 at the contact point (shown as 124), as shown in FIG. 13. Preferably, this step 204 includes applying thermal energy to the contact point (shown as 124) so as to form a thermosonic bond. In another embodiment, the holding step includes holding the element 102 in position over the contact point (shown as 124) with an ultrasonic tool which includes an integral vacuum port (not shown) for holding the element 102.

A next step 206 includes connecting the top electrode 108 of the element 102 to a second conductive trace 118 of the substrate 104, as shown in FIG. 14. Preferably, this is done by wirebonding a wirebond 110 to connect the bonding trace 134 of the top electrode 108 to the second conductive trace 118. The wirebond 110 electrically couples the top electrode 108 of the element 102 to a second conductive trace 118 disposed on the package body 114 so as to provide external electrical connection to the top electrode 108. It should be recognized that this connecting step may be performed by any of the commonly known techniques, including the use of conductive adhesives.

A last step 208 includes sealing the lid 112 to the seal ring 128 by a sealing process to provide hermetic sealing. The sealing process is selected from the group consisting of cold welding, resistance welding and seam welding, as shown in FIG. 15. Preferably, seam welding is used due to the reduced stresses imparted to the element 102 and reduce costs associated with seam welding.

Although various embodiments of this invention have been shown and described, it is to be understood that various modifications and substitutions, as well as rearrangements and combinations of the preceding embodiments, can be made

by those skilled in the art, without departing from the novel spirit and scope of this invention.

What is claimed is:

Claims

1. An ultrasonically mounted piezoelectric device, comprising:

a piezoelectric element having an upwardly facing surface and a downwardly facing surface, and having a top electrode disposed on the upwardly facing surface and a bottom electrode disposed on the downwardly facing surface;

a substrate having at least one substantially upwardly facing surface and having at least two conductive traces thereon for connection to the piezoelectric element;

the bottom electrode of the piezoelectric element having an ultrasonically formed coupling with one of the conductive traces of the substrate.

2. The piezoelectric device of claim 1, wherein the coupling includes a conductive bump interposed between the bottom electrode of the piezoelectric element and the conductive trace, the bump having an ultrasonically formed bond with the bottom electrode and the conductive trace.

3. The piezoelectric device of claim 1, wherein the coupling includes a conductive bump interposed between the bottom electrode of the piezoelectric element and the conductive trace, the conductive bump ultrasonically bonded to the bottom electrode of the piezoelectric element and the bump having an solder reflow connection to the conductive trace.

4. The piezoelectric device of claim 1, wherein the piezoelectric element is an AT-cut quartz crystal, and wherein the device produces a frequency-temperature response having a Bechmann curve with an inflection temperature of about 25 degrees C or less.

5. The piezoelectric device of claim 1, wherein the piezoelectric element comprises a GT-cut quartz crystal, and wherein the bottom electrode of the piezoelectric element has the ultrasonically formed bond substantially near a center of the element.

6. A method of ultrasonically mounting a piezoelectric element to a substrate, comprising the steps of:

providing a substrate with at least one substantially upwardly facing planar surface and at least one conductive point electrically coupled with at least one conductive trace disposed on the substrate, and a piezoelectric element with an upwardly facing surface including a top electrode and a downwardly facing surface including a bottom electrode;

positioning the bottom electrode of the element to be in contact with the at least one conductive point of the substrate; and

applying ultrasonic energy to the conductive point so as to bond the bottom electrode to the conductive point.

7. The method of claim 6, further comprising a wirebonding step before the positioning step wherein at least one conductive bump is wirebonded to the substrate, the bump defining the conductive point electrically coupled with the at least one conductive trace.

8. The method of claim 6, wherein the positioning step includes holding the element in position over the contact point, and applying downward pressure to the element so as to form a contact point between the bottom electrode and the conductive point, and applying ultrasonic energy to the upwardly facing surface of the element at a point substantially opposite the contact point so as to form an ultrasonic bond at the conductive point.

9. The method of claim 6, wherein the applying ultrasonic energy step includes applying thermal energy to the contact point so as to form a thermosonic bond at the contact point.

10. The method of claim 6, wherein the providing step includes providing the substrate with a sealing surface and a lid suitable for sealing to the sealing surface, and further comprising the steps of:

connecting the top electrode of the element to a second conductive trace of the substrate; and

sealing the lid to the seal ring.

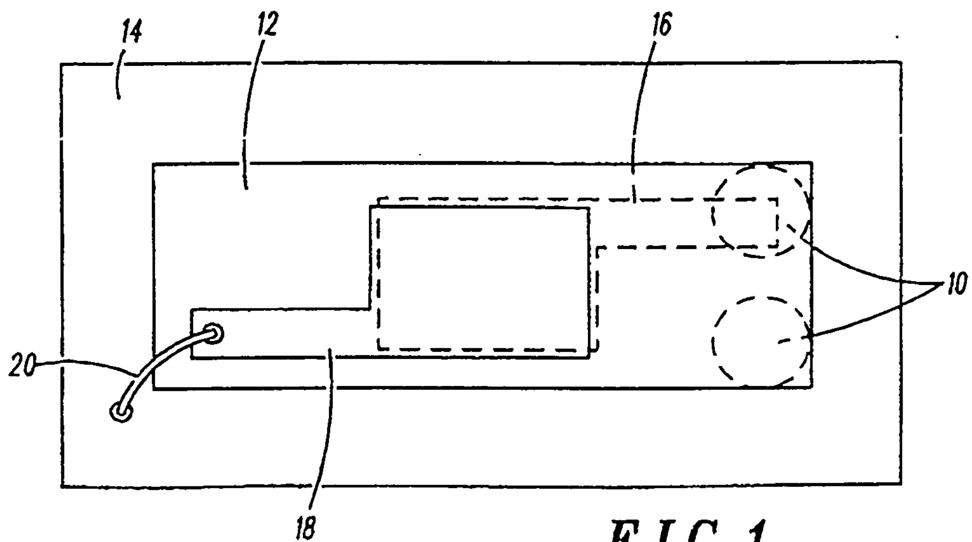

FIG.1
—PRIOR ART—

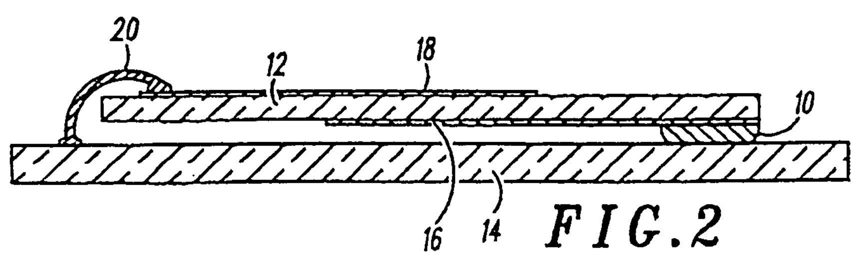

FIG.2
—PRIOR ART—

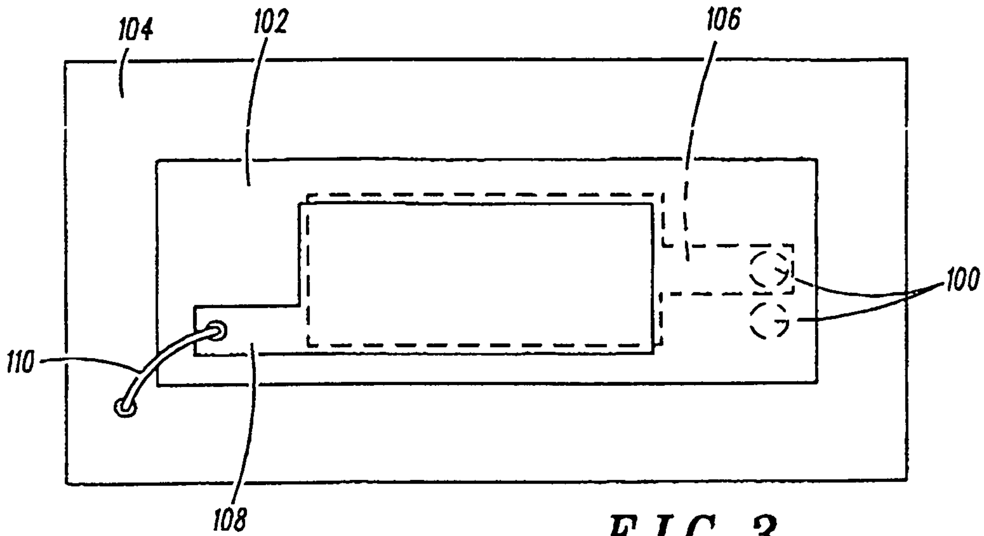

FIG.3

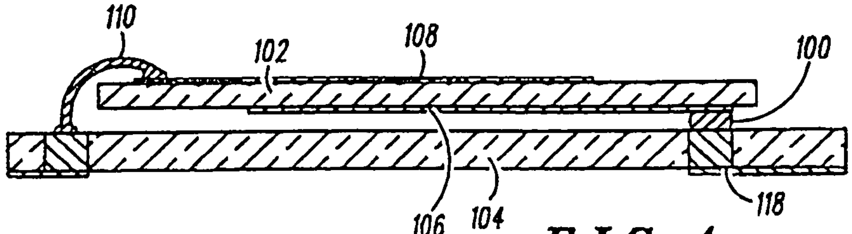

FIG.4

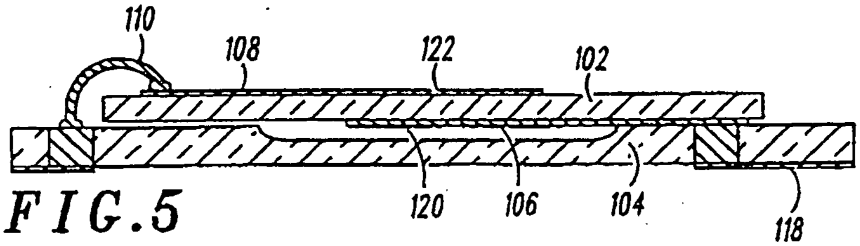

FIG.5

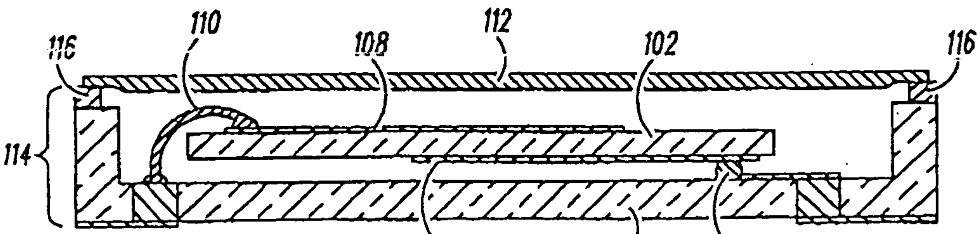

FIG.6

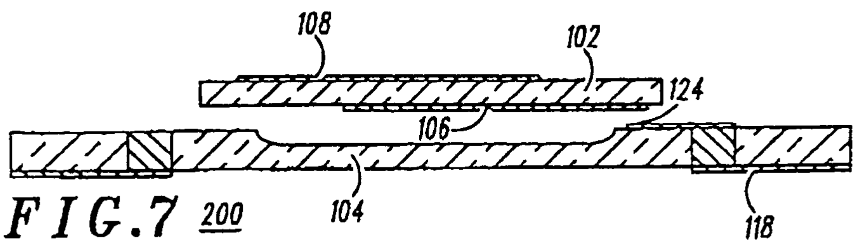

FIG.7 200

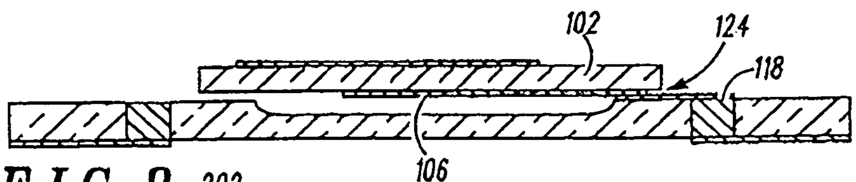

FIG.8 202

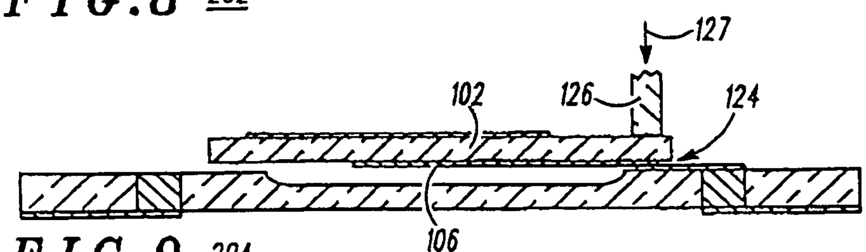

FIG.9 204

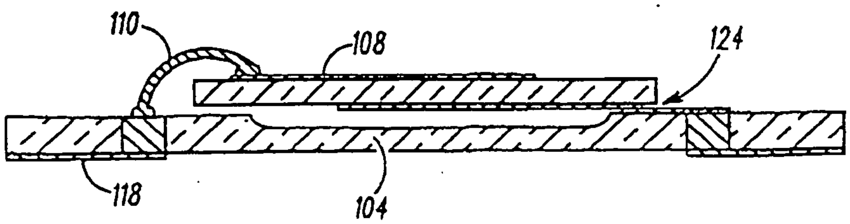

FIG.10 206

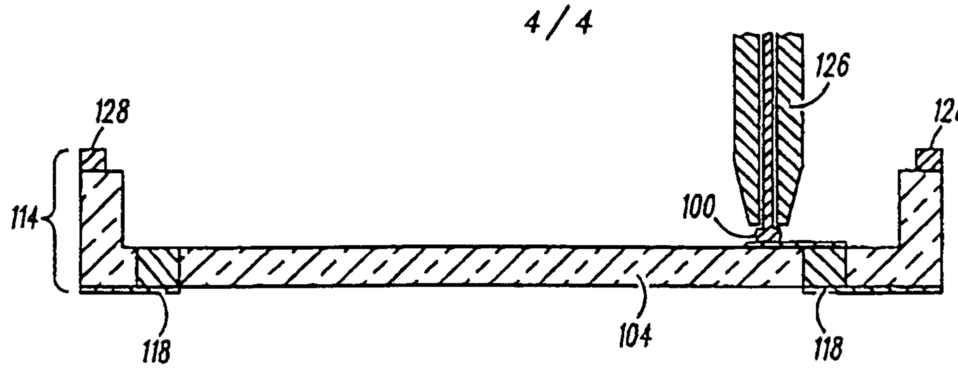

FIG.11

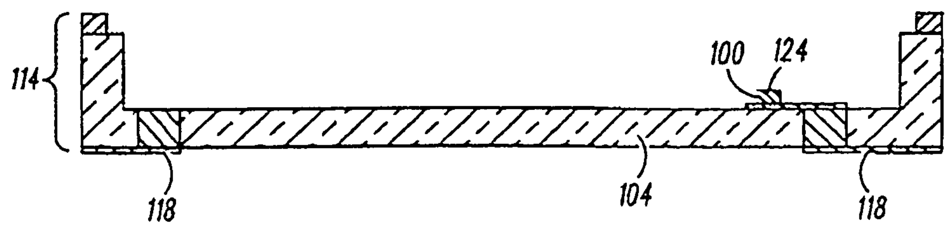

FIG.12

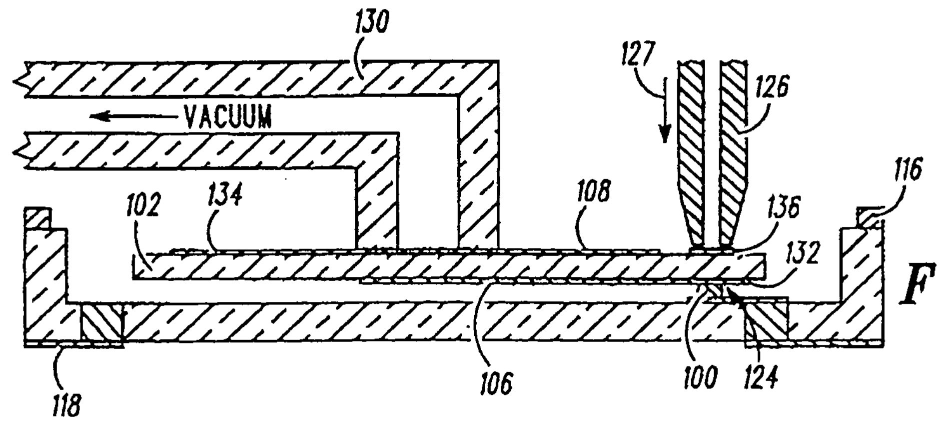

FIG.13

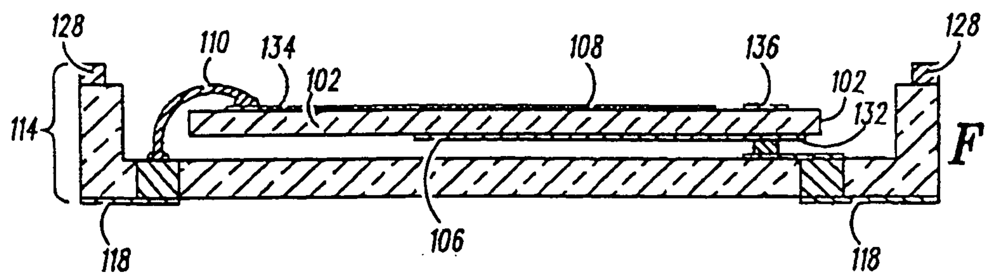

FIG.14

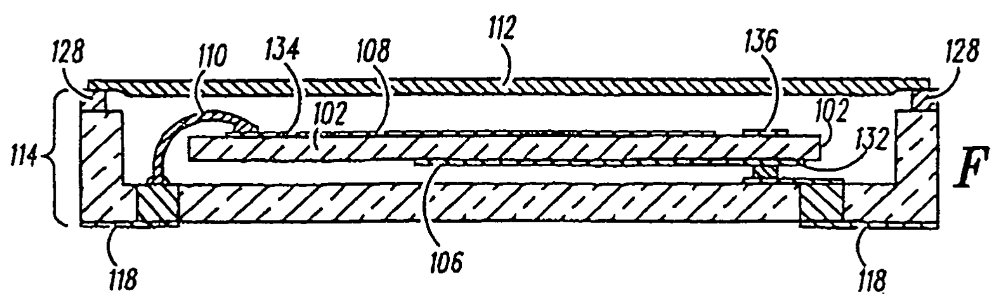

FIG.15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/15106

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H01L 41/22
US CL :310/328
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 310/328, 348, 313, 344, 311; 29/25.35

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS
search terms: Bechmann curve, electrode, piezoelectric, crystal cut, wire weld

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 5,571,363A (Brosig et al) 29 June 1994 (19/06/94), Col. 3, line 19 to col. 5, line 22.	1-4 5,6,7,8,9,10
Y	US 5,446,954A (Knecht et al) 5 September 1995 (05/09/95), col. 2, lines 37-47.	5
Y	US 5,302,550A (Hirota et al) 12 April 1994 (12/04/94), col. 2, lines 23-46.	6, 7, 8, 9
Y	US 5,250,870A (Fenlon et al) 5 October 1993 (05/10/93), col. 3 lines 1-44.	10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 NOVEMBER 1997	30 DEC 1997
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer TIMOTHY A. WILLIAMS Telephone No. (703) 308-1042

Form PCT/ISA/210 (second sheet)(July 1992)★